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(54) SYSTEM OF MONITORING OPERATING CONDITIONS OF ROTATING EQUIPMENT

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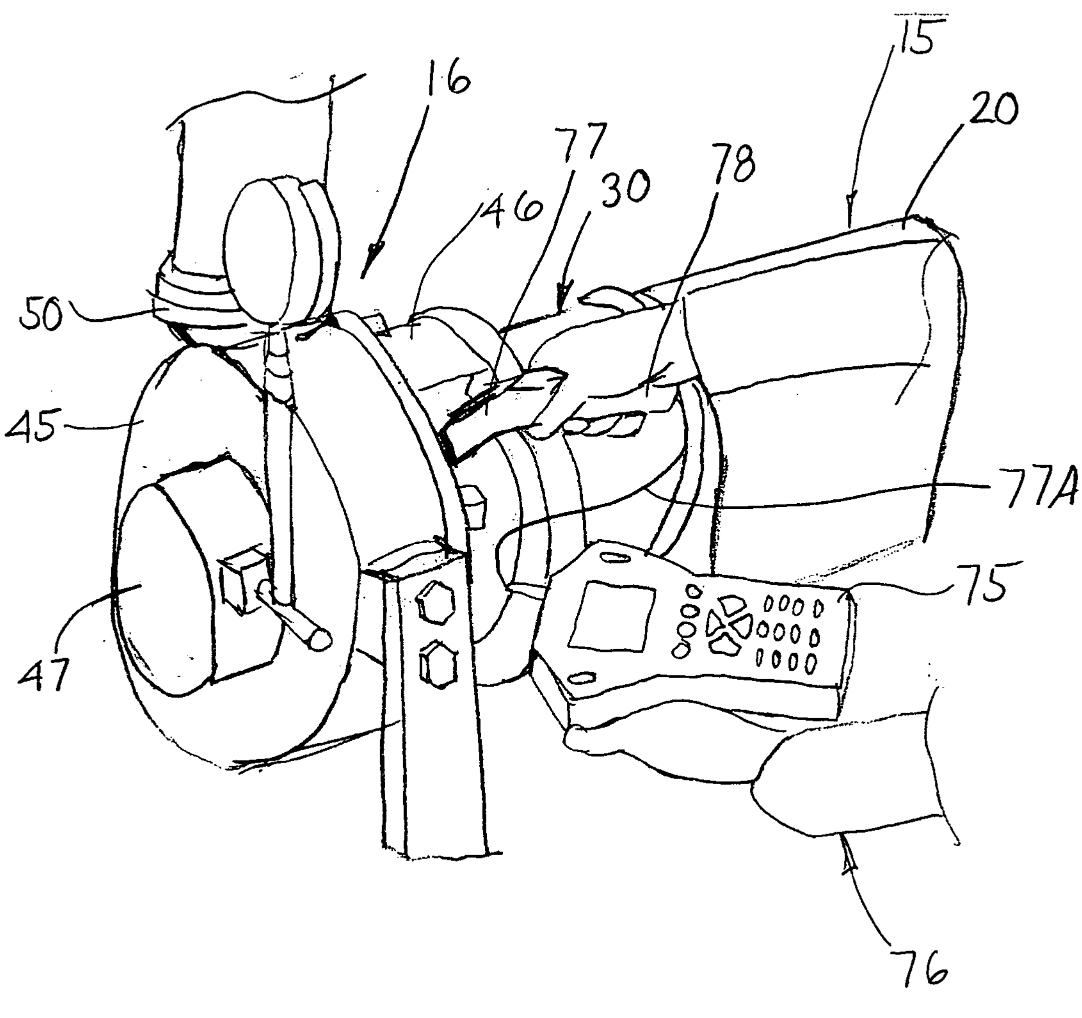
(57) **ABSTRACT**

A monitoring system for rotating equipment includes detection of temperature conditions in various areas of the system including motor and pump bearings, mechanical seal environment including seal flush, seal cooler and seal reservoir and process fluid temperature. The monitoring system allows for the prediction of component failures and a proactive repair schedule which minimizes if not eliminates component damage.



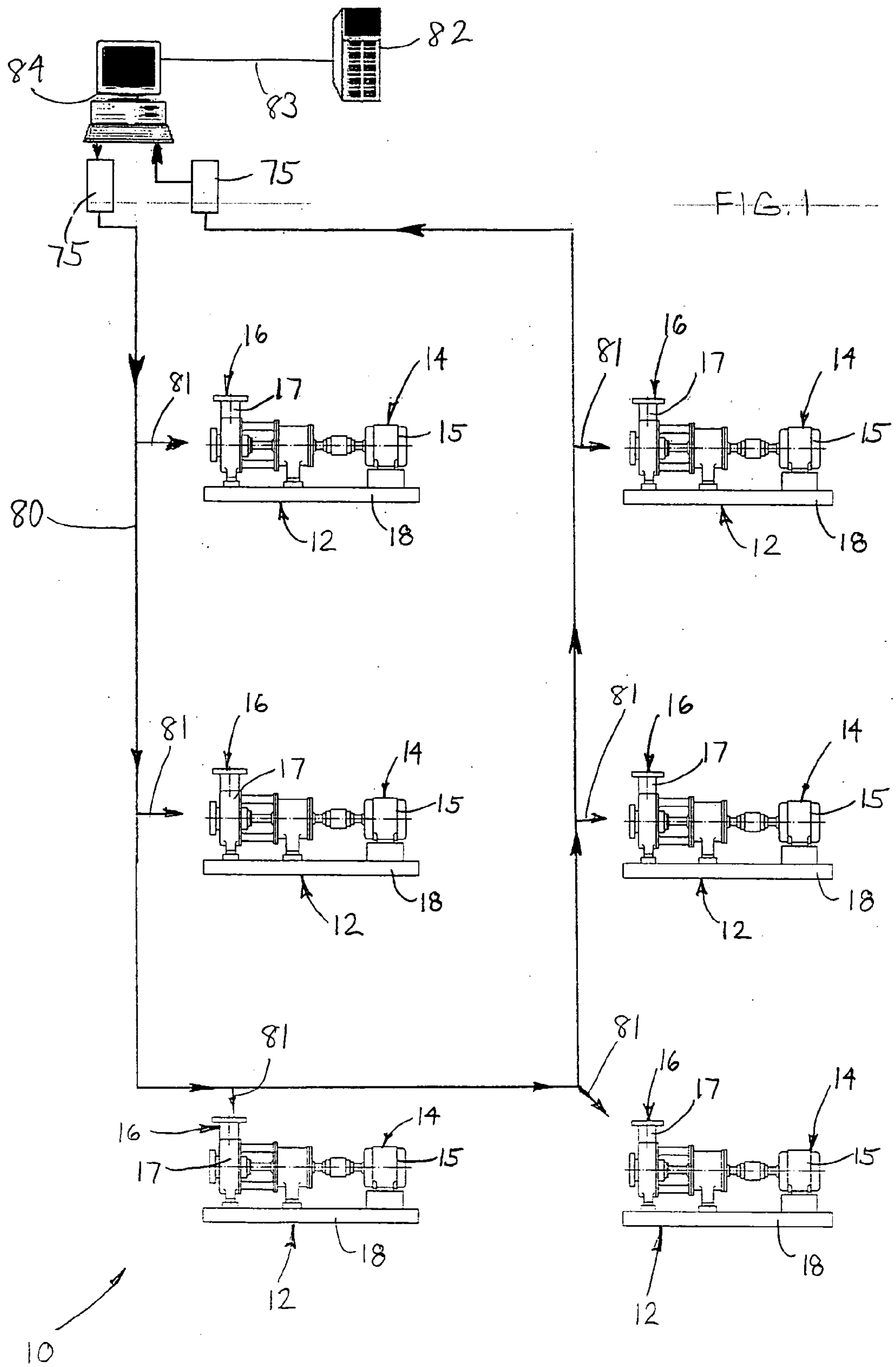


FIG. 1

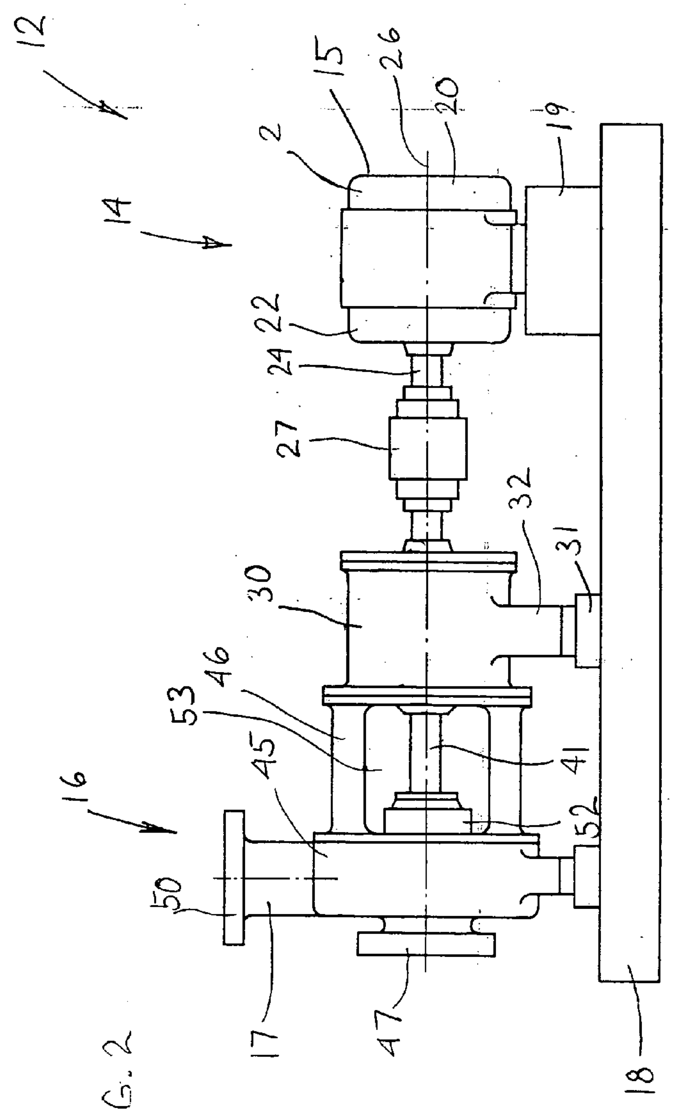

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FIG. 2

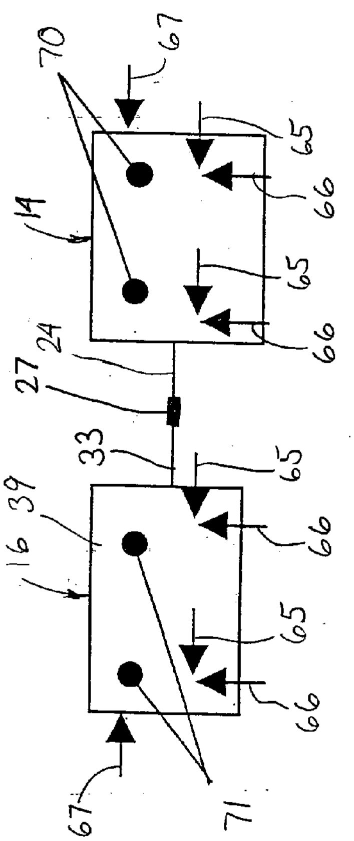
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FIG. 3

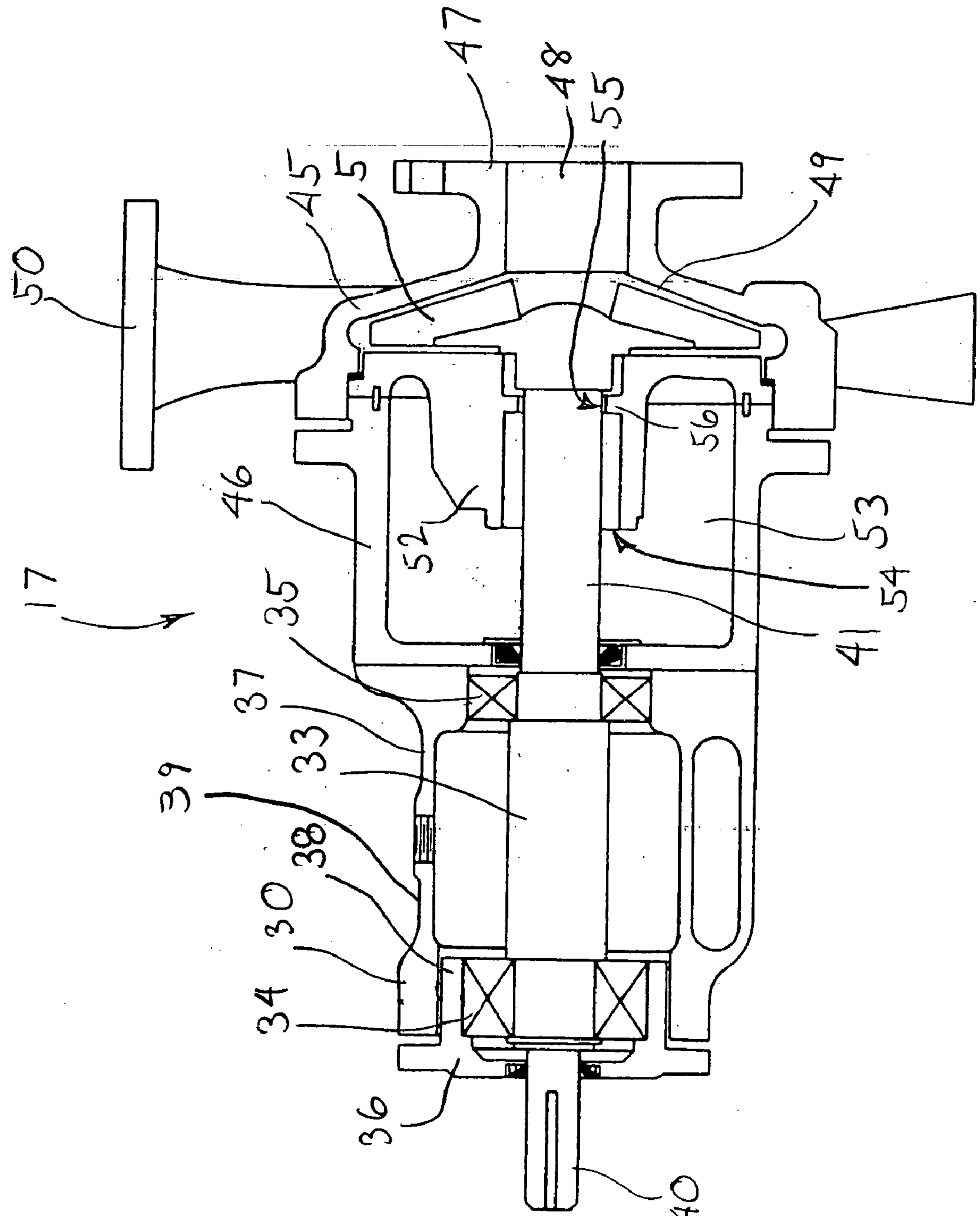

FIG. 4

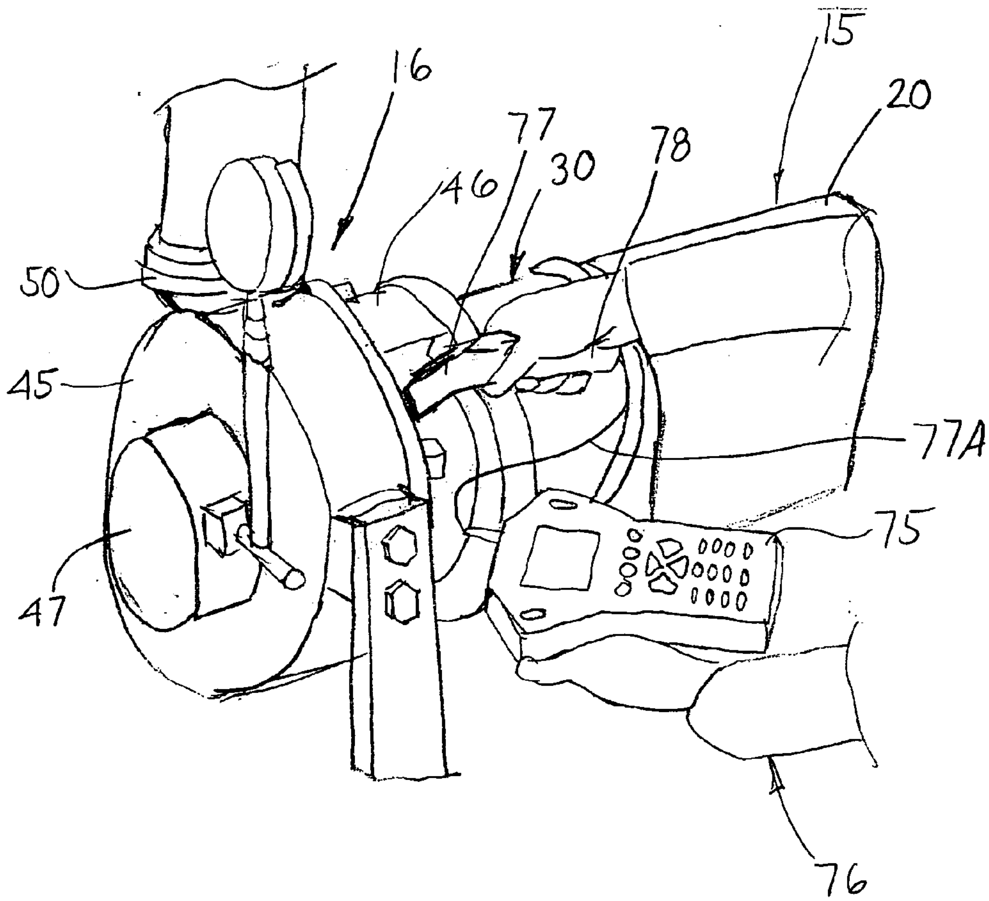

FIG. 5

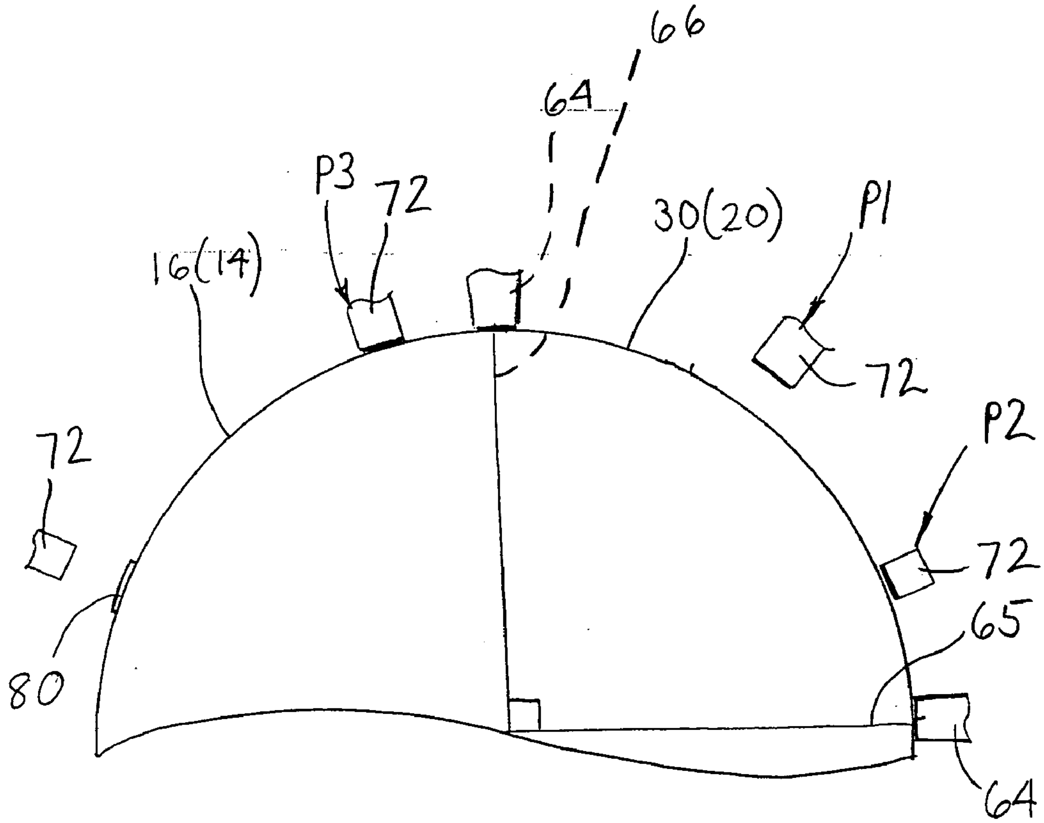

FIG. 6

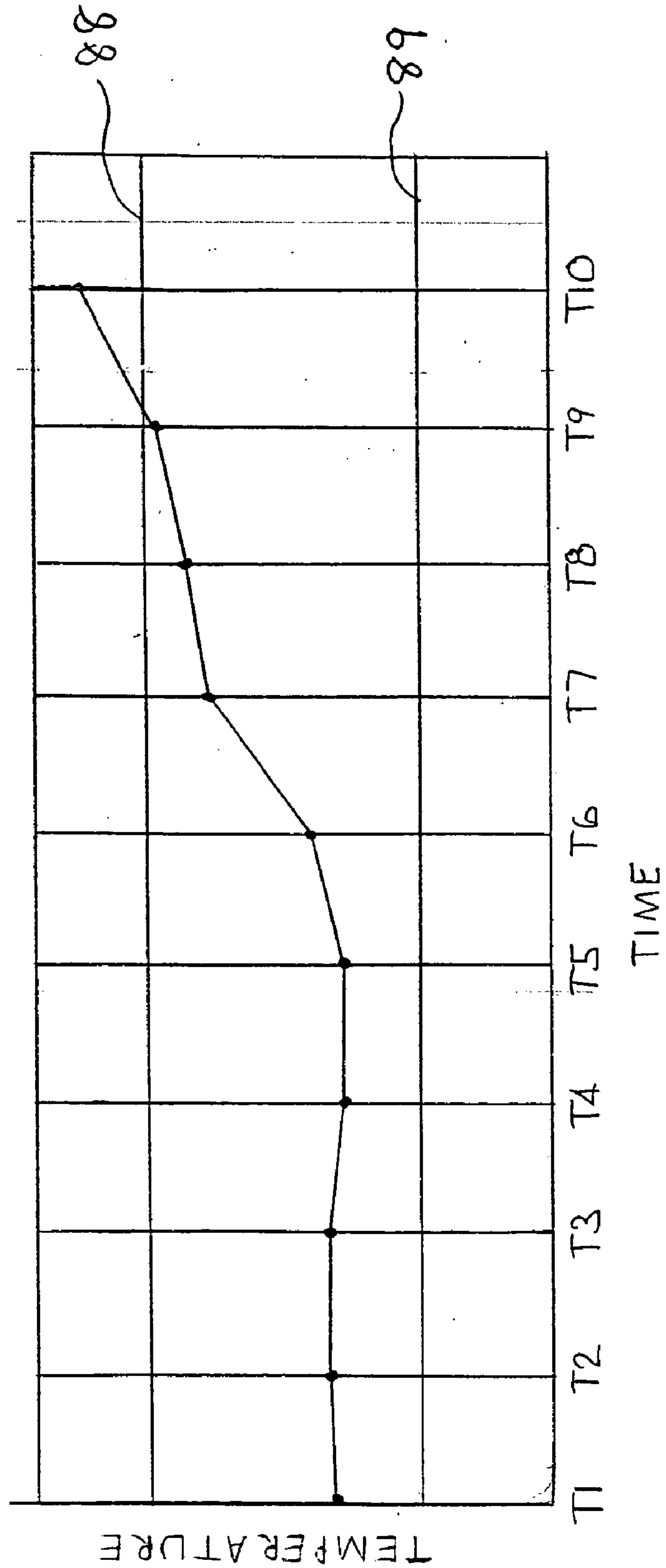

FIG. 7

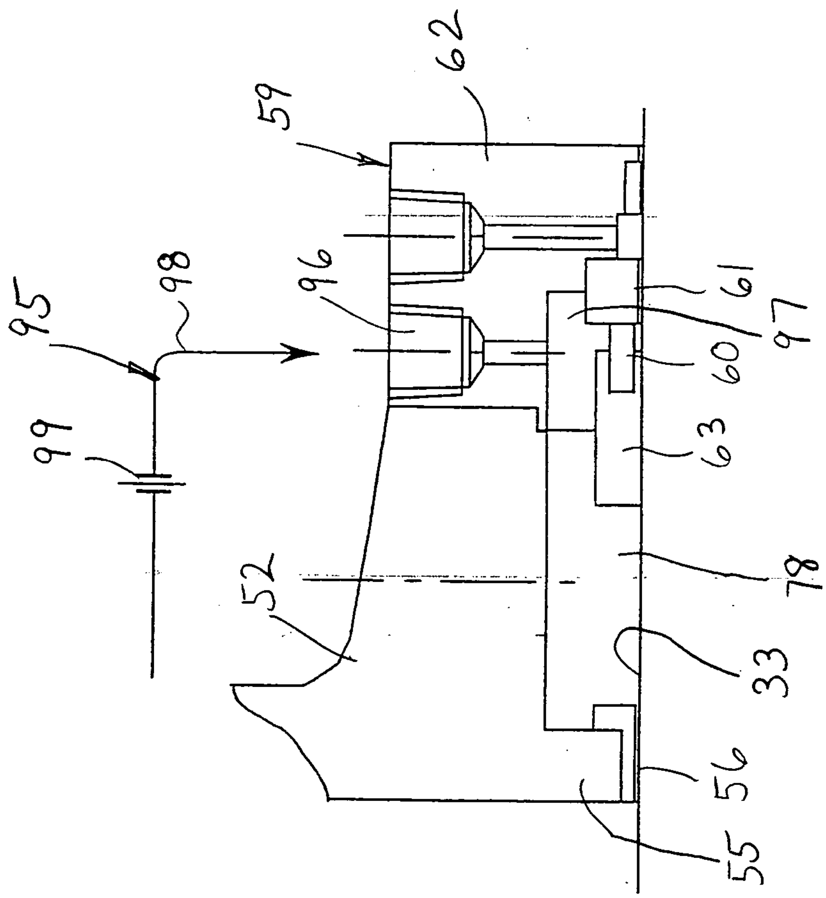

FIG. 9

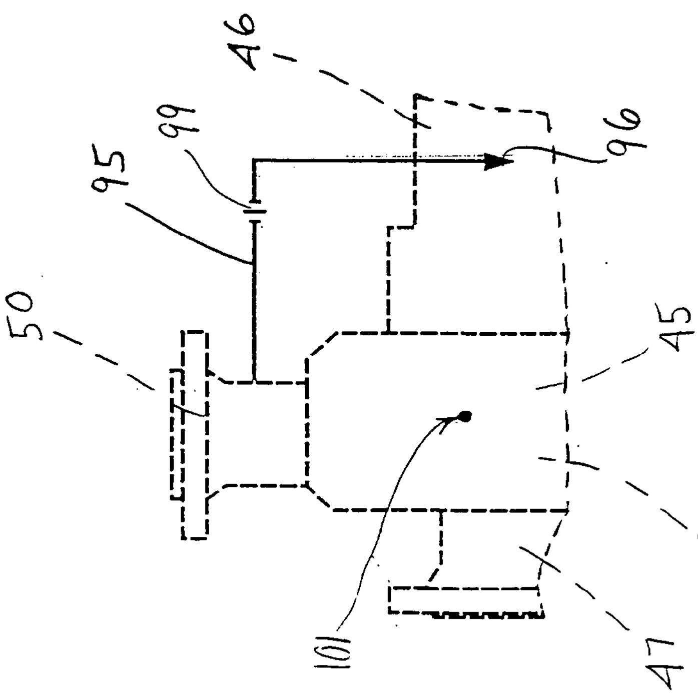

FIG. 8

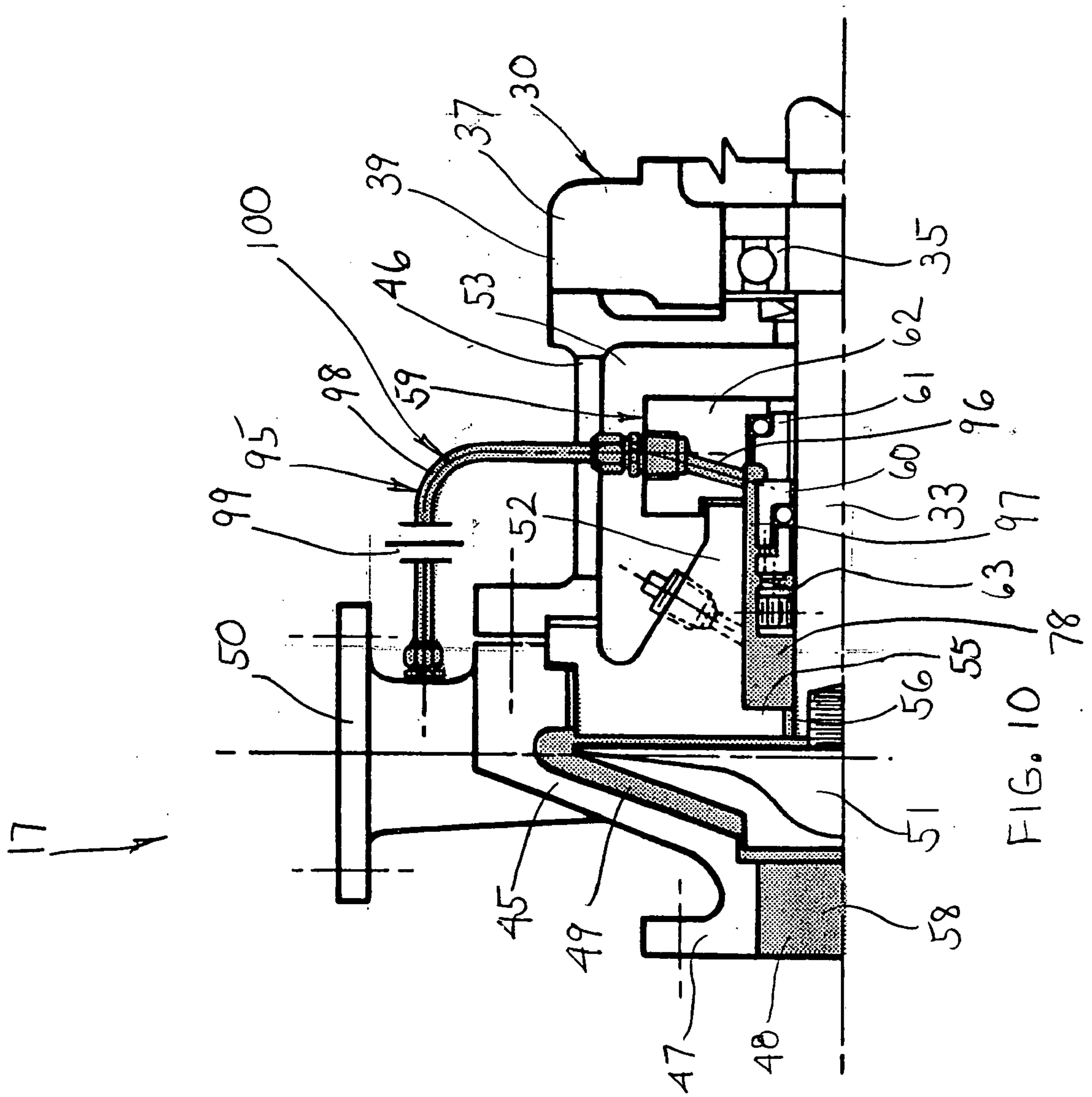
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FIG. 10

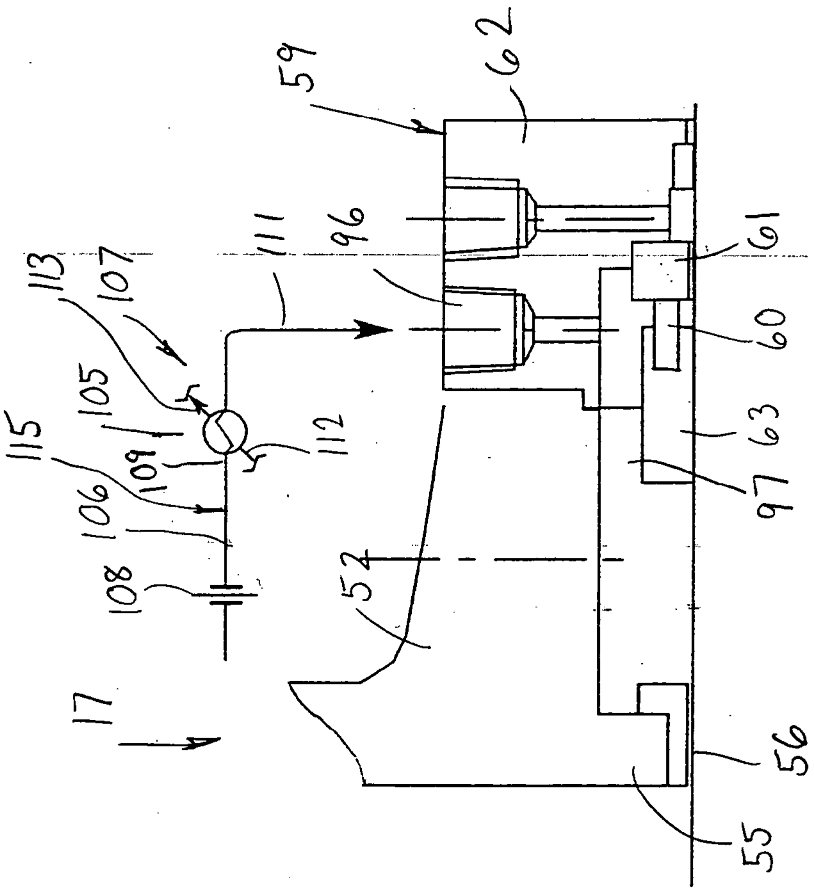
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FIG. 12

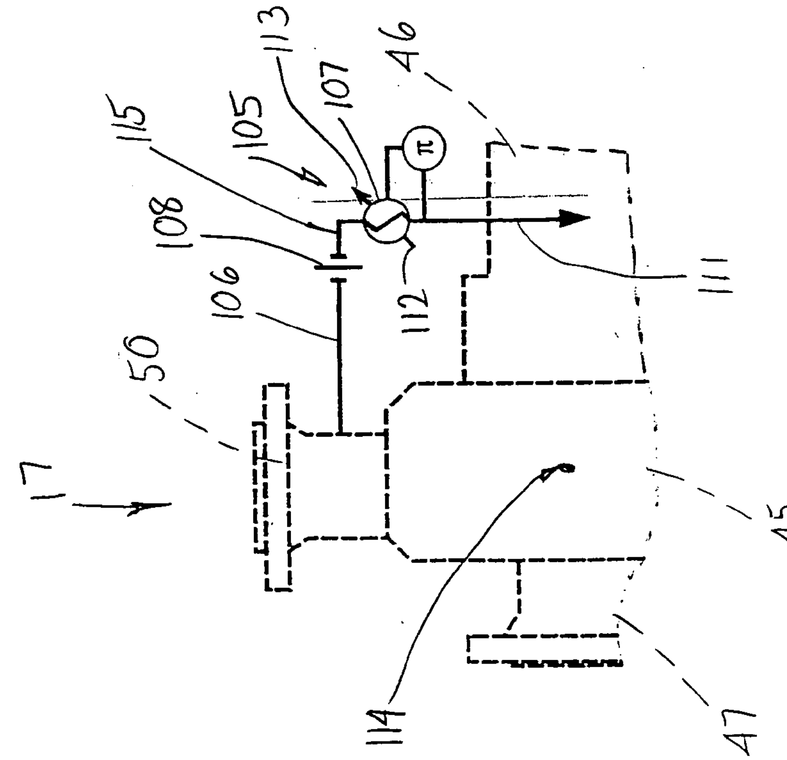
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FIG. 11

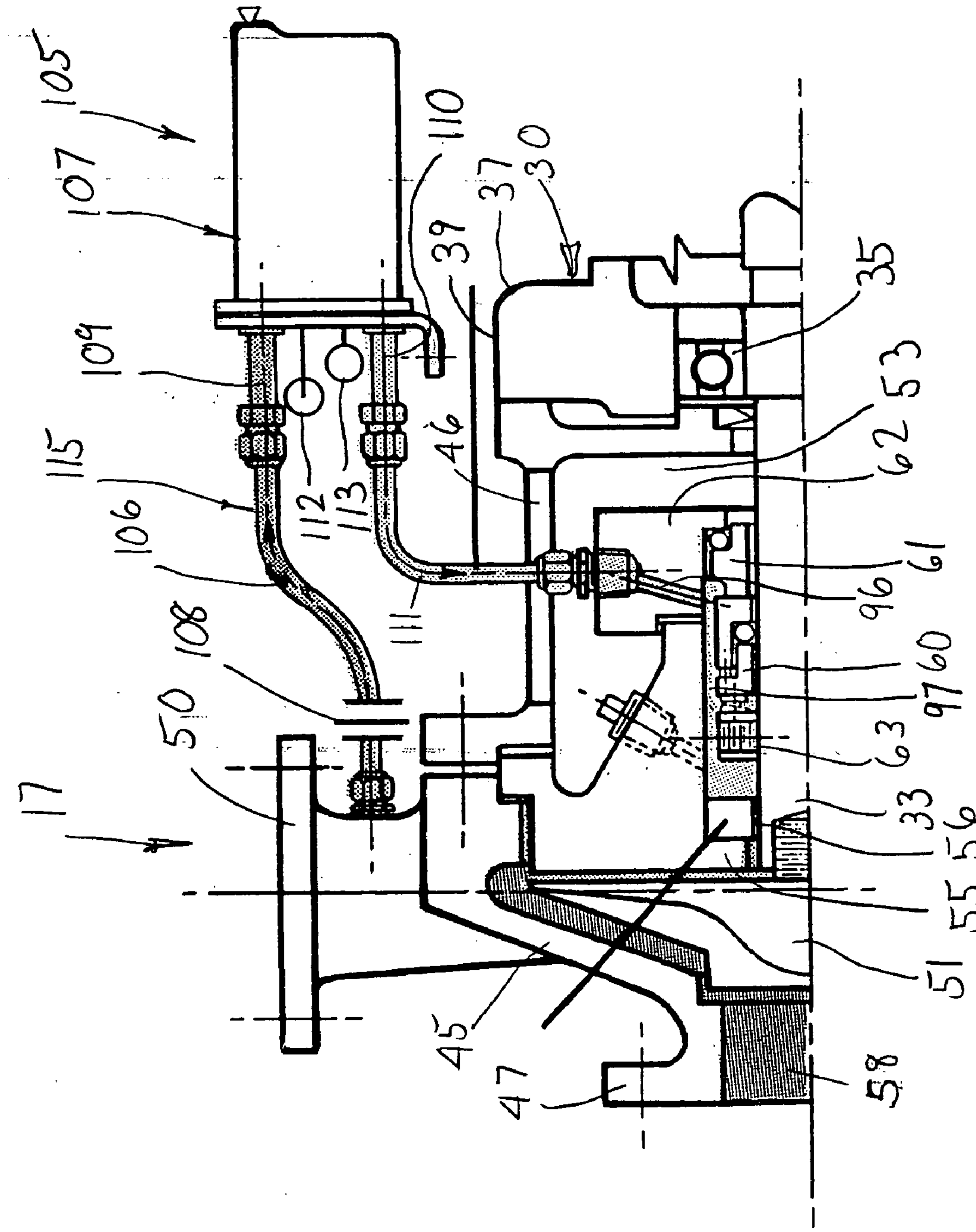
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FIG. 13

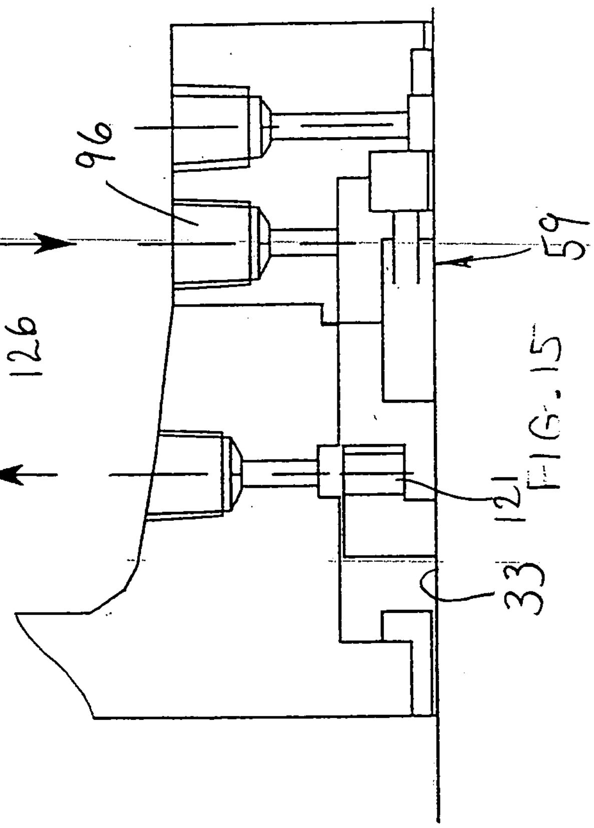

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FIG. 15

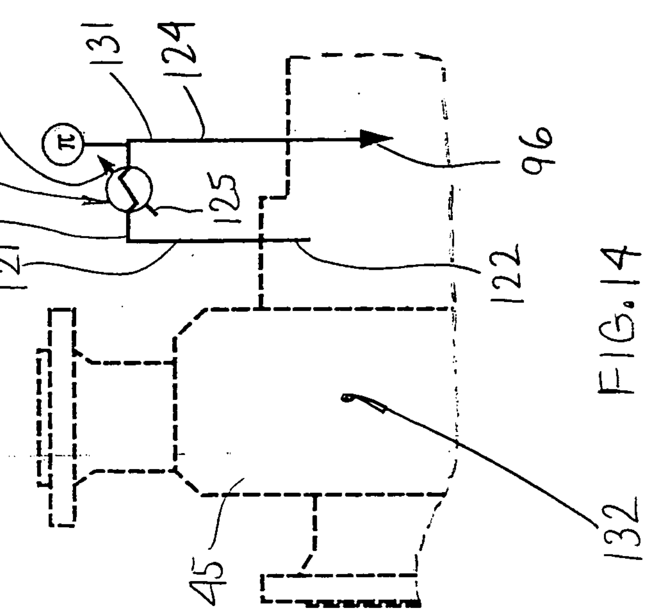

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FIG. 14

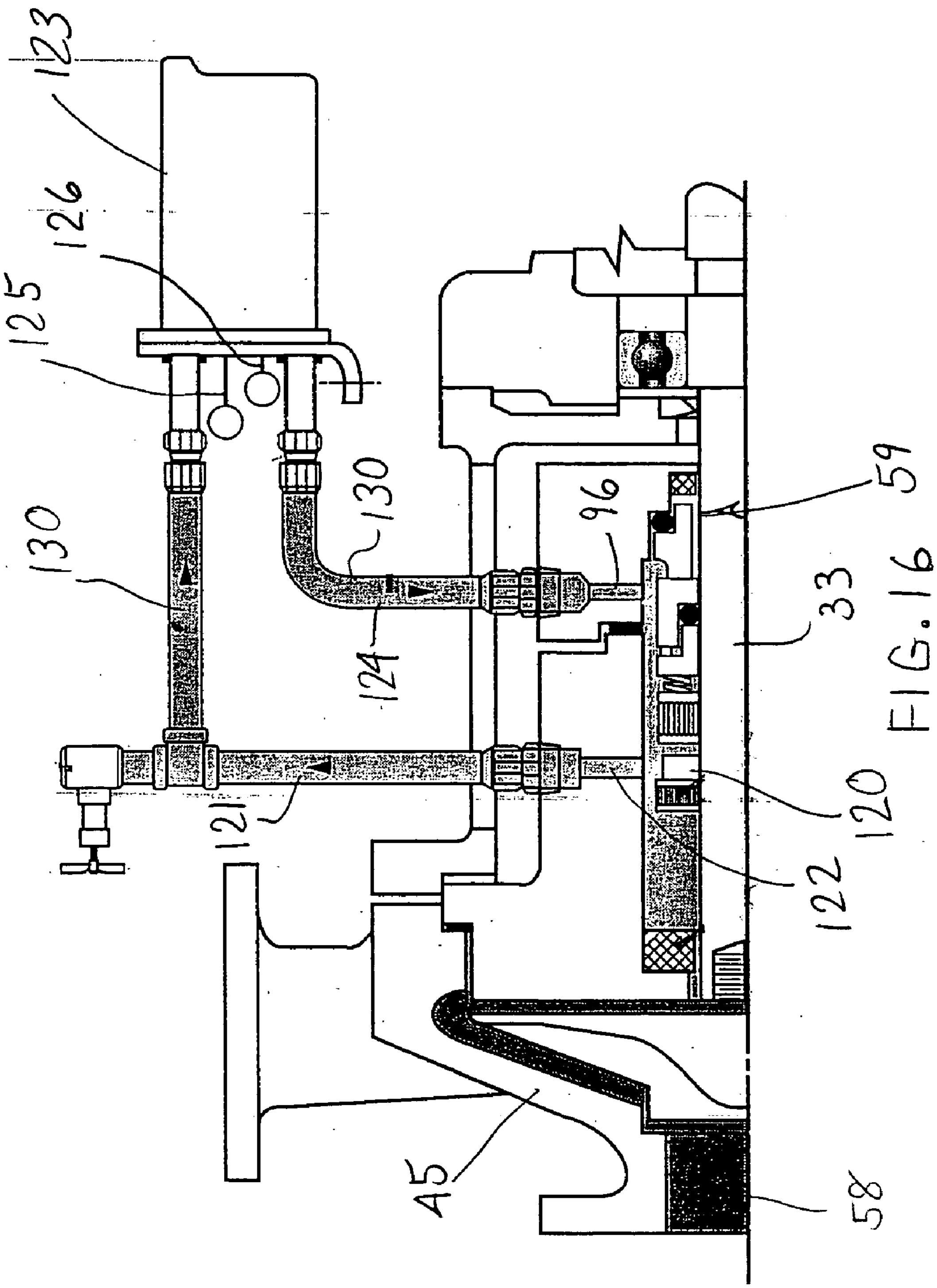

FIG. 16

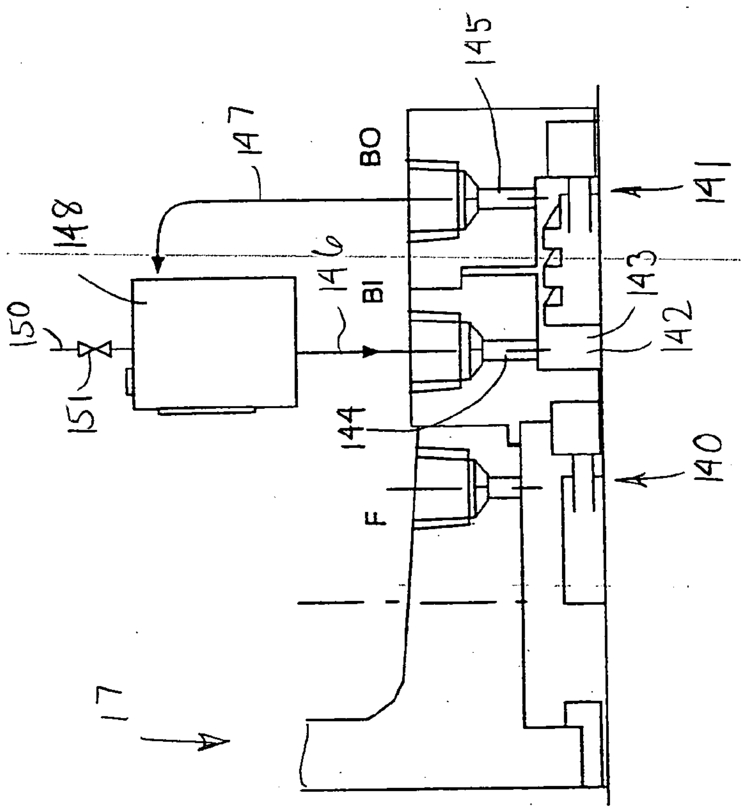
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FIG. 18

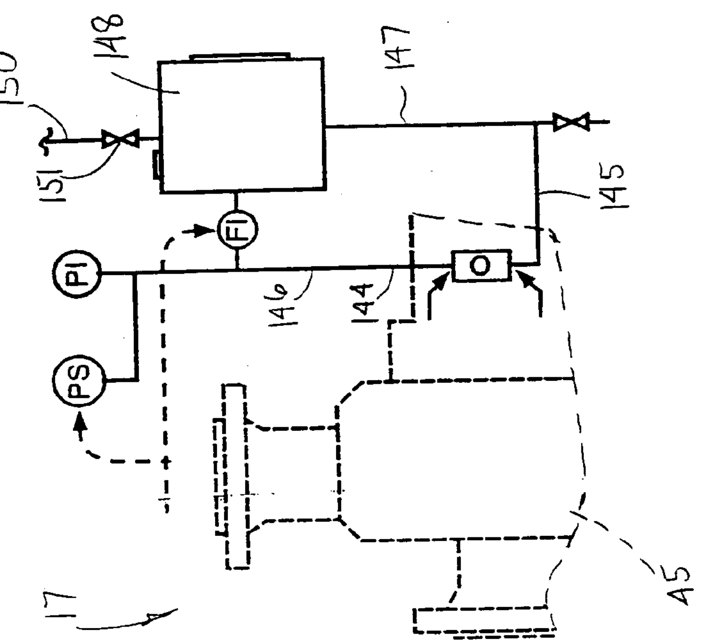
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FIG. 17

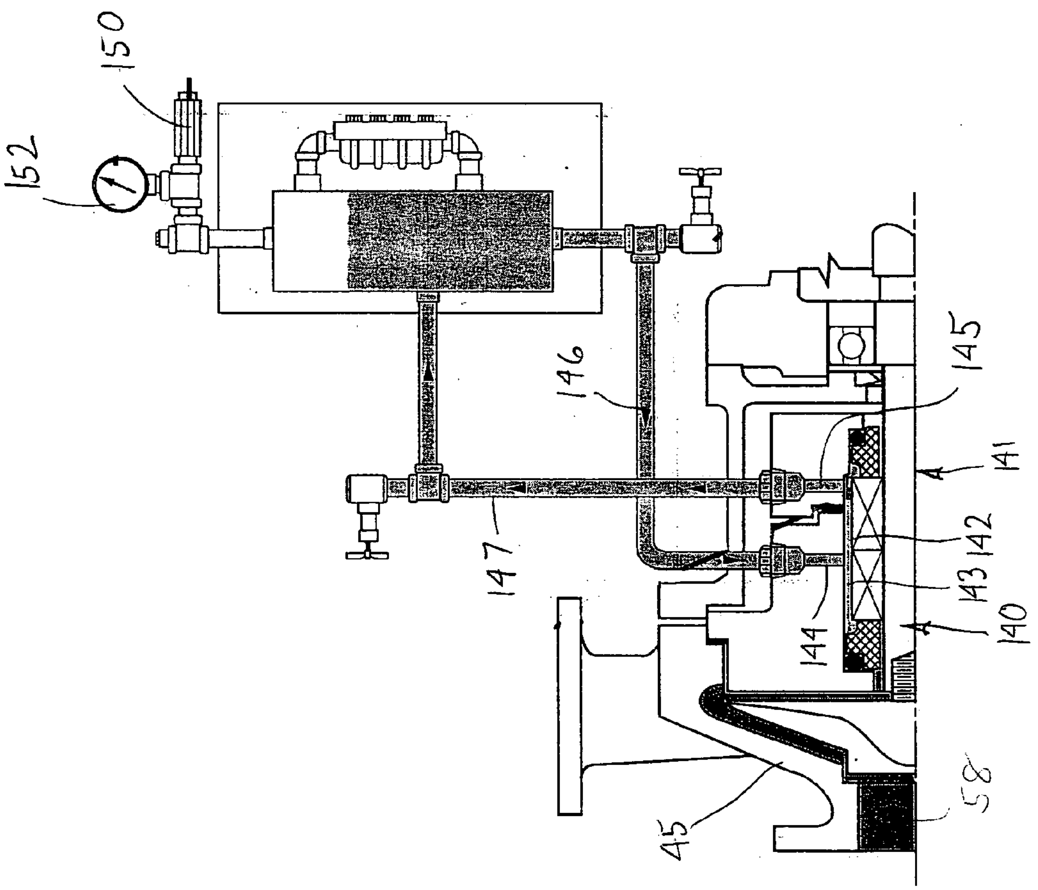

FIG. 19

SYSTEM OF MONITORING OPERATING CONDITIONS OF ROTATING EQUIPMENT

FIELD OF THE INVENTION

[0001] The invention relates to a condition monitoring system for rotating equipment and, more particularly, to a system for detecting operating conditions of such rotating equipment in an effort to prevent equipment failures.

BACKGROUND OF THE INVENTION

[0002] Manufacturing and production facilities include rotating equipment therein such as motors and pumps. These motors and pumps include various components which may undergo wear or have equipment defects which cause failure of the components. Such components include bearings on the motor and pump, and mechanical seals which prevent leakage of the process fluid being pumped into the pump components along the shaft. Any failures of the components of the rotating equipment may cause significant expense both in the repair of the rotating equipment as well as down time during the manufacturing or processing of product.

[0003] In an effort to identify equipment damage prior to complete failure thereof, it is known to collect vibration data on the bearings of rotating equipment. Vibration data typically is collected on two locations on each of the motor and pump which locations correspond to the bearings therein. More particularly as to each bearing location, vibration data is collected for both the horizontal and vertical directions. It is important that the horizontal and vertical directions be at right angles and aligned with each other. In addition, to the horizontal and vertical data, axial data is collected for each of the motor and pump.

[0004] Vibration data can indicate equipment problems such as unbalance, bearing defects, gear defects, blade/impeller faults, structural resonance problems, rubbing, loss of lubrication, oil whirl, cavitation/recirculation problems, equipment distress and seal distress. As the equipment components begin to fail, vibration levels typically increase and if left undetected, catastrophic damage may occur to the equipment and result in extensive repair costs as well as lost production.

[0005] When increases in vibration levels lead to an indication of failure, repairs are required to the equipment although these repairs are less than when catastrophic failure is reached. Once the vibration levels increase, a window of time is provided between the start of excessive vibration and a catastrophic failure point such that it is critical to identify and correct and problems during this failure window. However, an undesirable feature associated with vibration analysis is that vibration is indicative of the presence of some damage such that this damage still must be repaired.

[0006] Furthermore, vibration analysis requires that the horizontal, vertical and axial vibration measurements be at precise orientations. This may be difficult, however, for measurements taken with handheld vibration detectors, particularly where the equipment material is non-metallic. For example, if a horizontal measurement is not taken perpendicular to the vertical measurement, results would be affected. Accordingly, use of manual vibration detectors is more likely to introduce human error into the process, although the use of handheld measurement devices remains desirable since this is more cost effective than using a fully automated sensing system comprising permanent sensors and monitoring equipment.

[0007] It is an object of the invention to provide a system of monitoring rotating equipment which proactively or predictively identifies component problems prior to the occurrence of damage in the rotating equipment.

[0008] The invention relates to a monitoring system which collects temperature data of critical areas on the rotating equipment. This temperature monitoring system is capable of detecting problems before damage occurs and may be used in combination with vibration analysis and other sampling techniques to provide a comprehensive monitoring system for the rotating equipment.

[0009] Generally, the temperature monitoring system of the invention monitors bearing temperatures in the motor and pump, the process fluid temperature and various areas of the mechanical seal environment including seal flush, seal cooler and seal reservoir. Typically, unusual fluid flow in the equipment components generates undesirable and out of the ordinary heat which causes temperature increases that may be detected before actual failure and damage of the components. This may significantly reduce repair costs and down time of the rotating equipment.

[0010] The condition monitoring system furthermore provides more reliable results with bearings since only a single temperature reading is made on each bearing wherein the temperature reading does not require that the temperature detector be oriented at a precise angle. Still further, the temperature monitoring system allows other equipment environments to be monitored, particularly, the seal environment wherein conditions leading to failure cause little if any vibration.

[0011] Other objects and purposes of the invention, and variations thereof, will be apparent upon reading the following specification and inspecting the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] **FIG. 1** is a diagrammatic plan view of a processing facility having a plurality of machines and an on-site computer terminal for analyzing data.

[0013] **FIG. 2** is an enlarged side elevational view of one machine comprising rotating equipment which includes a pump and motor therefor.

[0014] **FIG. 3** is a diagrammatic view of vibration detection locations and temperature collection locations on the rotating equipment.

[0015] **FIG. 4** is a side cross sectional view of the pump.

[0016] **FIG. 5** is a perspective view of temperature data being collected from a machine.

[0017] **FIG. 6** is a diagrammatic end view of a machine with a vibration detector illustrated in precise horizontal and vertical orientations and a temperature detector illustrated in multiple unrestricted locations.

[0018] **FIG. 7** is a graph of a sample temperature plot for collected temperature data.

[0019] FIG. 8 is a partial side view of an API Plan 11 piping configuration for the pump.

[0020] FIG. 9 is a partial cross sectional side view of the seal arrangement for the pump of FIG. 8.

[0021] FIG. 10 is a more detailed partial cross sectional side view of the pump and seal.

[0022] FIG. 11 is a partial side view of an API Plan 21 piping configuration for the pump.

[0023] FIG. 12 is a partial cross sectional side view of the seal arrangement for the pump of FIG. 11.

[0024] FIG. 13 is a more detailed partial cross sectional side view of the pump and seal.

[0025] FIG. 14 is a partial side view of an API Plan 23 piping configuration for the pump.

[0026] FIG. 15 is a partial cross sectional side view of the seal arrangement for the pump of FIG. 14.

[0027] FIG. 16 is a more detailed partial cross sectional side view of the pump and seal.

[0028] FIG. 17 is a partial side view of an API Plan 53 piping configuration for the pump.

[0029] FIG. 18 is a partial cross sectional side view of the seal arrangement for the pump of FIG. 17.

[0030] FIG. 19 is a more detailed partial cross sectional side view of the pump and seal.

[0031] Certain terminology will be used in the following description for convenience and reference only, and will not be limiting. For example, the words “upwardly”, “downwardly”, “rightwardly” and “leftwardly” will refer to directions in the drawings to which reference is made. The words “inwardly” and “outwardly” will refer to directions toward and away from, respectively, the geometric center of the arrangement and designated parts thereof. Said terminology will include the words specifically mentioned, derivatives thereof, and words of similar import.

DETAILED DESCRIPTION

[0032] Referring to FIG. 1, the invention relates to a condition monitoring system for rotating equipment, wherein temperature data is periodically collected for the equipment and analyzed to identify abnormal operating conditions. Such abnormal operating conditions, if left uncorrected, would eventually lead to failure of the rotating equipment. However, the monitoring system of the invention is capable of providing early warning of abnormal conditions before significant damage occurs to the rotating equipment. This temperature monitoring may be conducted by itself but preferably is conducted in combination with vibration monitoring.

[0033] Generally, a manufacturing or processing facility or plant 10 includes multiple machines 12 therein. FIG. 1 diagrammatically illustrates a layout of rotating equipment type machines 12 although the physical location and construction of the machines 12 varies widely from facility to facility. It will be understood that the layout of FIG. 1 is for illustrative purposes and that the system of the invention as described herein may be readily adapted to any facility.

[0034] Each machine 12 typically includes a drive component 14, such as a motor 15, and a driven component 16, such as a pump 17. The drive and driven components 14 and 16 are mounted on a base frame 18. It will be understood that the driven component 16 may also be a compressor, fan, gearbox or the like and the term “fluid” herein may refer to a liquid or a gas.

[0035] Referring to FIG. 2, the electric motor 15 is mounted on a pedestal 19 and has a housing 20 which includes an outboard end 21 and an inboard end 22. A pair of motor bearings are enclosed within the motor housing 20 proximate the opposite ends 21 and 22 respectively. These bearings support a rotatable drive shaft 24 which extends axially from the inboard end 22 and rotates about axis 26. The terminal end of the drive shaft 24 includes a shaft coupling 27.

[0036] The pump 17 includes a bearing housing 30 which is supported vertically on a pedestal 31 by a housing mount 32. Referring to FIGS. 2 and 4, the bearing housing 30 is generally cylindrical and includes a pump shaft 33 extending axially therethrough. The pump shaft 33 is rotatably supported by an outboard thrust bearing 34 and an inboard radial bearing 35. The thrust bearing 34 is supported within the housing 30 within an annular flange 38 of an end cap 36.

[0037] The bearing 35 directly contacts a housing wall 37 while the bearing 34 is supported on the wall 37 by the annular flange 38 on the end cap 36. The annular flange 38 mutually contacts the bearing 34 and the housing wall 37. In view of the foregoing, heat generated in the bearings 34 and 35 is conducted radially to the exterior housing surface 39.

[0038] The outboard end 40 of the pump shaft 33 projects axially from the bearing housing 30 and is connected to the coupling 27 in coaxial alignment with the motor shaft 24 so as to rotate in unison therewith. The inboard end 41 of the pump shaft 33 projects from the bearing housing 30.

[0039] Referring to FIG. 4, the pump 17 further includes a pump casing 45 and a seal housing 46 disposed intermediate the pump casing 45 and bearing housing 30. The pump casing 45 includes an inlet 47 that defines the suction eye 48 thereof which opens axially into an impeller chamber 49. The impeller chamber 49 opens radially into an outlet or discharge port S0 and includes a rotary impeller 51 therein. The pump shaft 33 projects axially into the impeller chamber 49 and is affixed to the impeller 51 so as to effect rotation thereof.

[0040] The pump 17 further includes a stuffing box 52 which opens axially into a seal chamber 53. The stuffing box 52 has an inboard end 54 which is spaced radially outwardly of the shaft 30 and an outboard end 55 which is constricted radially to define a throat 56 that communicates with the impeller chamber 49.

[0041] When the pump shaft 33 is driven by the motor 15, the impeller 51 rotates within the impeller chamber 49 in a conventional manner. The inlet 47 allows a process fluid 58 to flow into the impeller chamber 49 as seen in FIG. 10 whereby the impeller 51 discharges the process fluid 58 through the outlet 50 under pressure.

[0042] To prevent leakage of the process fluid 58 axially along the shaft 33 through the stuffing box 52, a mechanical seal is mounted to the stuffing box 52 such as the single mechanical seal **59** illustrated in **FIG. 10**. The mechanical seal **59** includes a pair of relatively rotatable annular seal rings **60** and **61**. A seal gland **62** is fastened to the stuffing box **52** and supports the seal ring **61** non-rotatably thereon. The other seal ring **60** is rotatably supported on the shaft **33** by a shaft sleeve **63**. A more detailed discussion of the mechanical seal environment will be provided herein.

[**0043**] During operation of the machine **12**, the various bearings in the motor **14** and the pump **17** may begin to wear, which could cause vibrations, or may be subject to vibrations due to abnormal conditions associated with the rotatable components of the machine **12** such as in the impeller **51** or due to cavitation or recirculation problems in the process fluid **58**.

[**0044**] To identify such vibrations, it is known to collect vibration data on the machine **12**. In particular, it is known to measure vibration levels occurring in the motor **15** and pump **17** in an effort to identify abnormal operating conditions. Such vibration measurements are taken adjacent the bearings of the pump **17** and motor **15**.

[**0045**] **FIG. 3** diagrammatically illustrates a drive component **14**, such as a motor, and a driven component **16**, wherein the components **14** and **16** have respective shafts **24** and **33** that are interconnected by a coupling **27**. To monitor vibrations, handheld data collection units have been used to collect vibration data through a magnetic vibration sensor **64** which attaches to the metal housings of the drive component **14** and the driven component **16** as diagrammatically illustrated in **FIG. 6**.

[**0046**] For each bearing location, a horizontal vibration reading **65** and a vertical vibration reading **66** are taken. Additionally, axial vibration readings **67** are taken. As seen in **FIG. 6**, the horizontal reading **65** is taken by the sensor **64** which is magnetically affixed to the housing **30** or **20** to avoid inadvertent sensor movement during a test. Thereafter, the vertical reading **66** is taken by the same sensor **64** wherein the phantom lines in **FIG. 6** indicate a second sensor position. It is important, however, that the horizontal and vertical orientations of the sensor **64** be perpendicular to each other otherwise vibration readings would be affected. Further, solid contact of the sensor **64** with the housing **30** or **20** should be maintained to avoid movements which would introduce human error. Maintaining secure contact, however, may prove difficult for non-metallic housings.

[**0047**] While vibration analysis is useful in avoiding catastrophic failure of rotating equipment, such analysis also has drawbacks. In particular, each pair of bearings on a machine component requires five (5) total readings and precise positioning and orientation of the tip of the sensor **64**. Further, such testing identifies problems caused by vibrations associated with rotating components although such testing does not detect problems which may cause damage but do not result in vibrations, for example, as occurs in the mechanical seal.

[**0048**] Still further, vibrations typically result from damage existing within the machine **12**. Therefore, by the time excessive vibrations are detected, repairs may already be required for the machine **12** which will require that the machine **12** be taken out of service at least temporarily.

[**0049**] The temperature monitoring system of the invention, however, supplements vibration testing and improves upon the detection of problems in operating conditions before damage occurs.

[**0050**] More particularly as to how damage occurs, the earliest detection method is bearing oil analysis. Machine problems typically result in contaminants being found in the bearing oil. These contaminants provide the earliest warning of a problem and may be uncovered by oil analysis. However, oil analysis requires that oil samples be obtained and is a more complex testing process.

[**0051**] Next, heat levels begin to rise, and thereafter, vibration begins to occur once component damage occurs. Eventually, one or more machine components may fail resulting in costly repairs and downtime.

[**0052**] The system of the invention relates to a condition monitoring system which monitors the operating temperatures of selected components to identify abnormal operating conditions which may ultimately result in damage or failure of machine components. The monitoring system not only collects data and monitors rotating components such as bearings, but also allows for monitoring of the seal environment and fluids within the machine. This data is collected and compared to historical data from the same group of machines or to data obtained contemporaneously from different areas of the machine to provide early warning of potential problems.

[**0053**] The system generally involves first determining multiple temperature sensing locations on the machines, periodically collecting temperature data from such locations, and analyzing such data to identify and diagnose problems.

[**0054**] The temperature sensing locations are determined beforehand and physically marked on the machines. For a drive component **14** such as the motor **15**, at least one and preferably two temperature sensing locations **70** are defined thereon so as to indicate the operating temperature of the motor bearings. Often, the motor near the outboard bearing has a cover which does not facilitate conduction of heat from the bearing to the cover such that a temperature measurement on the outboard motor bearing may not be feasible. As such, only one temperature reading on the drive component **14** would be taken.

[**0055**] As to the driven component **16** such as the pump **17**, the pair of bearings **34** and **35** are typically located so as to conduct heat to the outer housing surface **39**. As such, two temperature readings are usually taken from sensor locations **71** on the driven component **17**.

[**0056**] As a result, possibly four but more likely three temperature readings associated with the bearings are taken for the motor **15** and pump **17**. These readings can provide an early indication of bearing problems. Furthermore, only one temperature reading is required for each bearing thereby reducing the number of readings as compared to those required for vibration testing.

[**0057**] Temperature readings also are easier to obtain since the temperature reading is not dependent upon the physical orientation of a temperature sensor **72**. As seen in **FIG. 72**, equivalent temperature readings may be taken from any of the locations identified by reference numeral **72** therein. In the first position indicated by **P1**, the sensor **72** is approximately one inch away from the outer housing surface, while the sensor **72** is closely adjacent to or in contact in the positions P2 and P**3** respectively.

[**0058**] The preferred data collector **75** for taking and storing temperature readings is a hand held manual data collector sold by Rockwell Automation of Milwaukee, Wis. under the model name Enpac 1200A. The Enpac 1200A is designed to download and store a predefined list of machines and to collect and store specific temperature readings for each machine **12** through a temperature sensor unit **77** attached by a cable **77**A. This data collector **75** is illustrated in **FIG. 5** being held by a test person or tester **76**. The sensor unit **77** has a hand piece **78** that is pointed at a surface to be tested and triggered to collect a temperature reading which is stored electronically within internal storage on the data collector **75**.

[**0059**] The primary requirement for the sensor unit **77** is that the surface being detected must be a dark surface. As seen in **FIG. 6**, if a dark surface is not provided, a separate plate **80** may be mounted to the housing surface being tested.

[**0060**] Alternatively, the plate **80** could be a bar code attached to the housing surface to provide a suitable color surface and also identify the location being tested. The sensor unit **77** of the data collector **75** reads this bar code **80** simultaneously with detection of the temperature to input both location and temperature data into the internal storage of the data collector **75**.

[**0061**] Not only is the data collector **75** capable of detecting the operating temperatures associated with the bearings, the data collector **75** also is used to detect the operating temperature of other machine components such as the process fluid **58** and the environment of the mechanical seal. As described herein, the sensing locations associated with the process fluid **58** and mechanical seal **59** will vary depending upon the specific configuration of the machine **12** and the specific piping plan being used thereon.

[**0062**] When initially setting up a data collection program, a survey or audit is conducted of the machines **12** in the facility **10**. The specific sensing locations are assigned for each machine **12**. Further, the physical location of the machines **12** is evaluated to determine or map out the most efficient route which the human collector **76** will walk to collect the temperature data. One route **80** is diagrammatically illustrated in **FIG. 1**, with data collection stops **81** provided at each machine **12**.

[**0063**] Once the sequence of machines **12** is mapped, this information is loaded into a main computer processing unit **82**. In the preferred method of the invention, this processing unit **82** is located offsite and accessed through a secure internet connection **83** via an on-site computer terminal **84**. The data collector **75** is plugged into a cable port on the on-site terminal **84** and the data collection route is downloaded thereto. The collector person **76** walks this route and enters temperature data at each machine **12** by aiming the sensor unit **75** at temperature sensing locations such as those associated with the bearings and mechanical seal. Each individual reading is stored in the data collector **75**.

[**0064**] At the end of the route or data collection procedure, the collector person **76** replugs the data collector **75** into the terminal **84** and electronically uploads the data to the processing unit **82**, which analyzes the data and returns a report to a facility engineer for evaluation and repair of any machines **12** having abnormal operating conditions.

[**0065**] It will be understood that the processing unit **82** may be eliminated and that all computer analysis may be conducted by the on-site terminal **84** through software. Furthermore, the system may be fully automated to ultimately eliminate manual collection of the temperature data.

[**0066**] As to the collected data, this data may be analyzed in a number of ways. Preferably such data is collected periodically, such as daily, weekly, monthly or annually. The frequency of this period will vary, for example, depending upon the critical nature of the equipment and the cost of the equipment. Upon the completion of each data collection procedure, such data is preferably compared to the historical data previously collected and stored.

[**0067**] **FIG. 7** illustrates an exemplary plot of data for a single sensor location as collected over ten (10) different time periods identified T1 through T10. The temperature plot includes two parallel horizontal lines which are vertically spaced apart and generally indicate upper and lower temperature levels **88** and **89**. These levels indicate basic levels which set off an alarm. However, when these levels are reached, serious component damage may already be present.

[**0068**] The following discusses monitoring of a temperature trend to provide an earlier indication of abnormal operating conditions. During the initial five test periods, the component temperature remained relatively steady. At the data collection period T6, an initial temperature increase was detected. At period T7, the rate of increase increased noticeably. This actual increase exceeds a predefined percentage of increase, preferably 10%, and accordingly, a warning of a 10% change is generated to prompt inspection of the component being tested. The percent change may trigger the alert either by exceeding a predefined rate or when the rate of increase is greater than the rate of increase of a previous test period which would likely indicate a worsening problem.

[**0069**] Therefore, at time T7, preemptive correction of a problem could be done before the temperature exceeded upper temperature limit **88**. With temperature analysis, such a temperature increase, for example as in a bearing, would occur when the rotating components had suffered little if any damage. In the seal environment, the temperature increase would be detected before seal damage occurred.

[**0070**] If the problem is not corrected immediately, a further notice would be generated when the temperature exceeds an alarm point for the temperature. If the component temperature continues to increase, a warning level would be reached when the temperature exceeds the upper level **88** indicating the component temperature was in a danger zone where component damage or failure was emminant. This three-tiered system of monitoring temperature trends is particularly applicable for bearings. For bearings, the alert temperature would be set at 180° F. which is the temperature that the bearing oil would begin to oxidize. The final warning level would be set at 200° F.

[**0071**] When analyzing the temperature data, several different approaches could be taken. At a basic level, the temperature data could be used only to determine if the current temperature levels were within upper and lower limits **88** and **89**. However, this might not take into account a machine that normally runs hot, unusually hot or cold environmental conditions which could elevate or decrease the component temperature, or running varying process fluids at different temperatures which also could affect the component temperature.

[**0072**] In view of the foregoing, it is more preferable that the last temperature data collected be compared against historical data for the same component or against contemporaneous data for different locations to diagnose a problem.

[**0073**] More particularly, the last temperature data can be compared against historical reference data for the same component. In one example, the reference data preferably is from the previous data collection time period as described above. In this case, T10 data would be compared against T9 data.

[**0074**] Alternatively, the reference data may be defined by a benchmark calculated from an average of temperature data collected over time, for example, the data collected at the beginning of the data collection program such as the data for periods T1 through T5. This benchmark would assume that the machines were in optimum operating condition wherein increases exceeding the predefined increase percentage would indicate abnormal operating conditions.

[**0075**] Additionally, the collected data may be analyzed for temperature trends caused by climate changes during different seasons, differences in temperatures of different process fluids, and differences in the environmental temperature of the facility **10**.

[**0076**] In addition to this ability to compare trends in historical temperature data, the temperature data at one location may also be compared against contemporaneous temperature data and other test data at other locations.

[**0077**] For example, **FIGS. 8-10** illustrate an API Plan **11** piping arrangement for the mechanical seal **59**. This piping plan includes a bypass flush **95** which provides a flow of process fluid **58** from the pump discharge **50** to the stuffing box **52**.

[**0078**] In particular, the seal gland **62** includes a flush inlet **96** which opens radially into a seal chamber **97** adjacent the seal rings **60** and **61**. A bypass pipe **98** is connected to the discharge **50** and the inlet **96** to permit process fluid **58** to flow therethrough to flush the seal rings **60** and **61** and then flows back to the impeller chamber **49** through the throat **56**. The bypass pipe **98** includes an orifice **99** to control fluid flow therethrough.

[**0079**] In this piping arrangement, the pump **17** and motor **15** preferably are each provided with five vibration sensing locations as described relative to **FIG. 3**. Further, the motor **15** has one temperature sensing location associated with the inboard bearing, while the pump **17** has two sensing locations disposed radially adjacent the bearings **34** and **35**. These temperature sensing locations identify heat buildup in the bearings and preferably would be analyzed based upon a comparison of the latest temperature data with the historical temperature data for the same sensing location to identify a percentage of increase which is excessive.

[**0080**] Also, a sensing location **100** is defined on the bypass pipe **95** to indicate the flush temperature and a sensing location **101** is provided on the pump casing **45** to indicate the process fluid temperature in the discharge **50**. Based upon contemporaneous measurements, the flush and process fluid temperatures should be proximate to each other. After a plug begins to form such as in the orifice **99**, however, a drop in flush temperature relative to the process fluid temperature would occur indicating the plugged orifice **99** in the bypass pipe **95**. Eventually, the temperature plot would increase due to heat generated in the seal **59** in the absence of flush caused by a plugged orifice **99**. This arrangement therefore shows the method of taking a temperature reading at a single location along a flow path to identify an abnormal flow condition.

[**0081**] **FIGS. 11-13** illustrate the pump **17** with an API **21** piping plan. The pump **17** includes the seal **59** in the same arrangement as **FIGS. 8-10**.

[**0082**] In this piping plan, a seal flush arrangement **105** is provided with an upstream pipe **106** and a heat exchanger **107**. The upstream pipe **106** is connected to the pump discharge **50** and includes a flow control orifice **108**. Hot process fluid is supplied therethrough to the heat exchanger **107**. The heat exchanger **107** includes an inlet **109** connected to the pipe **106** and an outlet pipe **110** connected to a downstream pipe **111**. The downstream pipe connects to the seal inlet **96**.

[**0083**] The heat exchanger **107** also includes a cooling water inlet **112** and a cooling water outlet **113**. For temperature data collecting, the motor **15** includes one sensing location and the pump **17** includes two sensing locations for the bearings as described above. Also, a sensing location **114** is defined on the pump case **45** and another location **115** is defined on the pipe **115** to warn of plugging of the orifice **108** similar to an API Plan **11** arrangement.

[**0084**] Still further, sensing locations are defined on the cooling water inlet **112** and outlet **113** and the temperature readings are compared with each other based upon contemporaneous data to warn if the heat exchanger **107** is not working properly. This therefore shows an alternate data collection method of monitoring operation of a component by collecting and comparing data from upstream and downstream sensing locations.

[**0085**] Referring to **FIGS. 14-16**, the pump **17** has an API plan **23** piping arrangement. In this arrangement, a circulating ring **120** is provided on the shaft **33** and an outlet flush pipe **121** is connected to an outlet bore **122**. Further, a heat exchanger **123** is connected to the pipe **121** as well as an inlet flush pipe **124** which pipes the flush fluid back in to the seal **59** through inlet **96**. The heat exchanger **123** includes a cooling water inlet **125** and a cooling water outlet **126**.

[**0086**] For temperature data collection, one sensing location is provided on the motor **15** and two sensing locations are provided on the pump **17** for the bearings. Further, sensing locations **130** and **131** are provided on the flush lines **121** and **124** respectively. Still further, a sensing location **132** is provided on the pump case **45** and further sensing locations are provided on the cooling water inlet **125** and outlet **125**. These sensor locations indicate proper functioning of the heat exchanger **123**.

[**0087**] Referring to **FIGS. 17-19**, the pump **17** has an API plan **53** piping arrangement. In this arrangement, a double seal arrangement is provide comprising an outboard seal **140** and an inboard seal **141** wherein a seal chamber **142** is defined therebetween. A pressurized barrier fluid **143** is supplied to the seal chamber **142** through a barrier fluid inlet **144** and a barrier fluid outlet **145**. The inlet **144** and outlet **145** are connected respectively to inlet and outlet pipes **146** and **147** which are further connected to a barrier fluid supply tank **148** to define a closed loop fluid supply system.

[**0088**] Further, a pressure source **150** is connected to the supply tank **148** and a block valve **151** may be provided thereon as seen in **FIGS. 17 and 18** and a pressure gauge **152** provided as seen in **FIG. 19**. A pressure switch, pressure gauge and flow indicator also may be installed on the inlet pipe **146**.

[**0089**] For temperature data collection, one sensing location is provided on the motor **15** and two sensing locations are provided on the pump **17** as described above. Further, temperature sensing locations may be defined on the barrier fluid in and barrier fluid out lines **146** and **147** to confirm proper flow of barrier fluid based upon a comparison of contemporaneous data from the different sensing locations. Further, data collection also includes the barrier fluid level and barrier fluid pressure to confirm proper operation thereof since low fluid levels and low pressure levels may be the cause of high temperature readings elsewhere in the seal system.

[**0090**] These plans are examples of data collection methods for the seal environment. These piping plans also may be combined. For example, a bypass flush of API Plan **11** could be added to the Plan **53** seal of **FIGS. 17-19** at which time temperature data would be taken for the pump case **45** and a bypass flush line as in **FIG. 8**.

[**0091**] In operation, the method for monitoring operating conditions is performed on rotating equipment which rotating equipment comprises the drive component **14** having the rotating drive shaft **24** in the driven component **16** having the shaft **33** and a rotating part connected to the shaft **33**. The rotating part may be a pump impeller **51** or the like. The rotating equipment further includes bearings therein which rotatably support the shafts **24** and **33** and the rotating part thereon. The rotating equipment also includes a process fluid and a primary mechanical seal preventing leakage of the process fluid along the shaft **33**. The mechanical seal includes passages therein containing a seal fluid such as a gland flush, barrier fluid or cooling water.

[**0092**] The method comprises the steps of providing the temperature data collector **75** having the temperature source **77**, and defining temperature sensing locations on the rotating equipment. The sensing locations are defined on the bearings and/or on the seal passages. Each temperature sensing location **70** or **71** associated with a bearing indicates an operating temperature of the associated bearing, and each sensing location associated with a seal passage indicates a temperature of a seal fluid such as the flush, barrier fluid or cooling water.

[**0093**] The method further includes the steps of performing a temperature data collection procedure on the rotating equipment which comprises the steps of manually positioning the temperature sensor **77** adjacent the rotating equipment, detecting surface temperatures on the rotating equipment by temperature readings of the sensing locations through the temperature sensor **77**, and storing temperature data from each said temperature reading in the data collector **75**. This data collection procedure is repeated periodically over time to develop historical data for each sensing location. Thereafter, the temperature data is analyzed by comparing each temperature data from a last data collection procedure with reference temperature data to identify temperature increases in the rotating equipment that indicate abnormal operating conditions of the bearings and/or the seal arrangement.

[**0094**] The reference temperature data may be defined by the temperature data of at least one prior data collection procedure wherein a plurality of prior data collection procedures may be performed and the results averaged to generate the reference temperature data. Alternatively, the prior data collection procedure may be defined by one data collection procedure performed immediately prior to the last collection procedure.

[**0095**] Although particular preferred embodiments of the invention have been disclosed in detail for illustrative purposes, it will be recognized that variations or modifications of the disclosed apparatus, including the rearrangement of parts, lie within the scope of the present invention.

What is claimed is:

1. A method for monitoring operating conditions on rotating equipment which rotating equipment comprises a drive component having a rotating shaft and a driven component having a rotating part connected to said shaft, said rotating equipment including bearings therein which rotatably support said shaft and said rotating part thereon, the method comprising the steps of:

providing a temperature data collector having a temperature sensor;

defining temperature sensing locations on said rotating equipment, each said bearing having one of said temperature sensing locations associated therewith which said sensing location is disposed proximate to said bearing such that a surface temperature on said rotating equipment at said temperature sensing location indicates an operating temperature of said associated bearing;

performing a temperature data collection procedure on said rotating equipment, said temperature data collection procedure comprising the steps of manually positioning said temperature sensor adjacent said rotating equipment, detecting surface temperatures on said rotating equipment by temperature readings of said sensing locations through said temperature sensor, and storing temperature data from each said temperature reading in said data collector;

repeating said data collection procedure periodically over time; and

analyzing said temperature data by comparing each said temperature data from a last said temperature data collection procedure performed with reference temperature data to identify temperature increases in said rotating equipment indicating abnormal operating conditions of said bearings.

2. The method according to claim 1, wherein said reference temperature data is defined by said temperature data of at least one prior said data collection procedure.

3. The method according to claim 2, wherein a plurality of said prior data collection procedures are performed to generate said reference temperature data.

4. The method according to claim 2, wherein said prior data collection procedure is defined by one said data collection procedure performed immediately prior to said last data collection procedure.

5. A method for monitoring operating conditions on rotating equipment which rotating equipment comprises a drive component having a rotating shaft and a driven component having a rotating part connected to said shaft, said rotating equipment including bearings therein which rotatably support said shaft and said rotating part thereon, said rotating equipment further including a process fluid and a primary seal arrangement preventing leakage of said process fluid along said shaft, said seal arrangement including passages therein containing a seal fluid, the method comprising the steps of:

providing a temperature data collector having a temperature sensor;

defining temperature sensing locations on said rotating equipment, said sensing locations being defined on said bearings and/or on said seal passages, each said temperature sensing location associated with a said bearing indicating an operating temperature of said associated bearing, and each said sensing location associated with a said seal passage indicating a temperature of said seal fluid;

performing a temperature data collection procedure on said rotating equipment, said temperature data collection procedure comprising the steps of manually positioning said temperature sensor adjacent said rotating equipment, detecting surface temperatures on said rotating equipment by temperature readings of said sensing locations through said temperature sensor, and storing temperature data from each said temperature reading in said data collector;

repeating said data collection procedure periodically over time; and

analyzing said temperature data by comparing each said temperature data from a last said temperature data collection procedure performed with reference temperature data to identify temperature increases in said rotating equipment indicating abnormal operating conditions of said bearings and/or said seal arrangement.

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